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METHOD OF UTILIZING FLOWABLE DEVICES IN WELLBORES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application takes priority from United States Patent Application Serial Nos. 60/136,656 filed August 5, 1999, and 60/147,127 filed May 28, 1999, each assigned to the assignee of this application.

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BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to oilfield wellbores and more particularly to wellbore systems and methods for the use of flowable devices in such wellbores.

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2. Background of the Art

Hydrocarbons, such as oil and gas, are trapped in subsurface formations. Hydrocarbon-bearing formations are usually referred to as the producing zones or oil and gas reservoirs or "reservoirs." To obtain hydrocarbons from such formations, wellbores or boreholes are drilled from a surface location or "well site" on land or offshore into one or more such reservoirs. A wellbore is usually formed by drilling a borehole of a desired diameter or size by a drill bit conveyed from a rig at the well site. The drill string includes a hollow tubing attached to a drilling assembly at its bottom end. The drilling assembly (also referred to herein as the "bottomhole assembly" or "BHA") includes the drill bit for drilling the wellbore and a number of sensors for determining a variety of subsurface or downhole parameters. The tubing usually is a continuous pipe made by joining relatively small sections (each

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section being 30-40 feet long) of rigid metallic pipe (commonly referred to as the "drill pipe") or a relatively flexible but continuous tubing on a reel (commonly referred to as the "coiled-tubing"). When coiled tubing is used, the drill bit is rotated by a drilling motor in the drilling assembly. Mud motors are most commonly utilized as

5 drilling motors. When a drill pipe is used as the tubing, the drill bit is rotated by rotating the drill pipe at the surface and/or by the mud motor. During drilling of a wellbore, drilling fluid (commonly referred to as the "mud") is supplied under pressure from a source thereof at the surface through the drilling tubing. The mud passes through the drilling assembly, rotates the drilling motor, if used, and

10 discharges at the drill bit bottom. The mud discharged at the drill bit bottom returns to the surface via the spacing between the drill string and the wellbore (also referred herein as the "annulus") carrying the rock pieces (referred to in the art as the "cuttings") therewith.

15 Most of the currently utilized drilling assemblies include a variety of devices and sensors to monitor and control the drilling process and to obtain valuable information about the rock, wellbore conditions, and the matrix surrounding the drilling assembly. The devices and sensors used in a particular drilling assembly depend upon the specific requirements of the well being drilled. Such devices

20 include mud motors, adjustable stabilizers to provide lateral stability to the drilling assembly, adjustable bends, adjustable force application devices to maintain and to alter the drilling direction, and thrusters to apply desired amount of force on the

drill bit. The drilling assembly may include sensors for determining (a) drilling parameters, such as the fluid flow rate, rotational speed (r.p.m.) of the drill bit and/or mud motor, the weight on bit ("WOB"), and torque of the bit; (b) borehole parameters, such as temperature, pressure, hole size and shape, and chemical and physical properties of the circulating fluid, inclination, azimuth, etc., (c) drilling assembly parameters, such as differential pressure across the mud motor or BHA, vibration, bending, stick-slip, whirl; and (d) formation parameters, such as formation resistivity, dielectric constant, porosity, density, permeability, acoustic velocity, natural gamma ray, formation pressure, fluid mobility, fluid composition, and composition of the rock matrix.

During drilling, there is ongoing need to adjust the various devices in the drill string. Frequently, signals and data are transmitted from surface control units to the drilling assembly. Data and the sensor results from the drilling assembly are communicated to the surface. Commonly utilized telemetry systems, such as mud pulse telemetry and acoustic telemetry systems, are relatively low data rate transfer systems. Consequently, large amounts of downhole measured and computed information about the various above-noted parameters is stored in memory in the drilling assembly for later use. Also, relatively few instructions and data can be transmitted from the surface to the drilling assembly during the drilling operations.

After the well has been drilled, the well may be completed, i.e., made ready for production. The completion of the wellbore requires a variety of operations, such as setting a casing, cementing, setting packers, operating flow control devices, and perforating. There is need to send signals and data from the surface during such completion operations and to receive information about certain downhole parameters. This information may be required to monitor status and/or for the operation of devices in the wellbore ("downhole devices"), to actuate devices to perform a task or operation or to gather data about the subsurface wellbore completion system, information about produced or injected fluids or information about surrounding formation. After the well has started to produce, there is a continuous need to take measurements of various downhole parameters and to transmit downhole generated signals and data to the surface and to receive downhole information transmitted from the surface.

The present invention provides systems and methods wherein discrete flowable devices are utilized to communicate surface-generated information (signals and data) to downhole devices, measure and record downhole parameters of interest, and retrieve from downhole devices, and to make measurements relating to one or more parameters of interest relating to the wellbore systems.

SUMMARY OF THE INVENTION

This invention provides a method of utilizing flowable devices to communicate between surface and downhole instruments and to measure downhole parameters of interest. In one method, one or more flowable devices are introduced into fluid flowing in the wellbore. The flowable device is a data carrier, which may be a memory device, a measurement device that can make one or more measurements of a parameter of interest, such as temperature, pressure and flow rate, and a device with a chemical or biological base that provides some useful information about a downhole parameter or a device that can transfer power to another device.

In one aspect of the invention, memory-type flowable devices are sent downhole wherein a device in the wellbore reads stored information from the flowable devices and/or writes information on the flowable device. If the flowable device is a measurement device, it takes the measurement, such as temperature, pressure, flow rate, etc., at one or more locations in the wellbore. The flowable devices flow back to the surface with the fluid, where they are retrieved. The data in the flowable devices and/or the measurement information obtained by the flowable devices is retrieved for use and analysis.

During drilling of a wellbore, the flowable devices may be introduced into the drilling fluid pumped into the drill string. A data exchange device in the drill string

reads information from the flowable devices and/or writes information on the flowable devices. An inductive coupling device may be utilized for reading information from or writing information on the flowable devices. A downhole controller controls the information flow between the flowable device and other
5 downhole devices and sensors. The flowable devices return to the surface with the circulating drilling fluid and are retrieved. Each flowable device may be assigned an address for identification. Redundant devices may be utilized.

In a production well, the flowable devices may be pumped downhole via a
10 tubing that runs from a surface location to a desired depth in the wellbore and then returns to the surface. A U-shaped tubing may be utilized for this purpose. The flowable devices may also be carried downhole via a single tubing or stored in a container or magazine located or placed at a suitable location downhole, from which
15 location the flowable devices are released into the flow of the produced fluid, which carries the flowable devices to the surface. The release or disposal from the magazine may be done periodically, upon command, or upon the occurrence of one or more events. The magazine may be recharged by intervention into the wellbore. The tubing that carries the flowable devices may be specifically made to convey the
20 flowable devices or it may be a hydraulic line with additional functionality. The flowable devices may retrieve information from downhole devices and/or make measurements along the wellbore. A plurality of flowable devices may be present in a wellbore at any given time, some of which may be designed to communicate

with other flowable device or other downhole device, thereby providing a communication network in the wellbore. The flowable devices may be intentionally implanted in the wellbore wall to form a communication link or network in the wellbore. A device in the wellbore reads the information carried by the flowable devices and provides such information to a downhole controller for use. The information sent downhole may contain commands for the downhole controller to perform a particular operation, such as operating a device. The downhole controller may also send information back to the surface by writing information on the flowable devices. This may be information from a downhole system or confirmation of the receipt of the information from surface.

Examples of the more important features of the invention have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

For a detailed understanding of the present invention, reference should be made to the following detailed description of the preferred embodiment, taken in

conjunction with the accompanying drawings, in which like elements have been given like numerals, wherein:

5 **Figure 1** is a schematic illustration of a drill string in a wellbore during drilling of a wellbore, wherein flowable devices are pumped downhole with the drilling fluid.

10 **Figure 2** is a schematic illustration of a wellbore during drilling wherein flowable devices are implanted in the borehole wall to form a communications line in the open hole section and wherein a cable is used for communication in the cased hole section.

15 **Figure 3** is a schematic illustration of a wellbore wherein flowable devices are pumped downhole and retrieved to the surface via a U-shaped hydraulic or fluid line disposed in the wellbore.

Figure 4 is a schematic illustration of a production well wherein flowable devices are released in the flow of the produced fluid at a suitable location.

20 **Figure 5** is a schematic illustration of a multi-lateral production wellbore wherein flowable devices are pumped down through a hydraulic line and released into the fluid flow of the first lateral and where information is communicated from the

first lateral to the second lateral through the earth formation and wherein flowable devices may also be released into the fluid flow of the second lateral to carry such devices to the surface.

5 Figure 6 is a block functional diagram of a flowable device according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

10 The present invention utilizes "flowable devices" in wellbores to perform one or more functions downhole. For the purpose of this disclosure, a flowable device means a discrete device which is adapted to be moved at least in part, by a fluid flowing in the wellbore. The flowable device according to this invention is preferably of relatively small size (generally in the few millimeters to a centimeter range in outer dimensions) that can perform a useful function in the wellbore. Such a device
15 may make measurements downhole, sense a downhole parameter, exchange data with a downhole device, store information therein, and/or store power. The flowable device may communicate data and signals with other flowable devices and/or devices placed in the wellbore ("downhole devices"). The flowable device may be programmed or coded with desired information. An important feature of the
20 flowable devices of the present invention is that they are sufficiently small in size so that they can circulate with the drilling fluid without impairing the drilling operations. Such devices preferably can flow with a variety of fluids in the wellbore. In another

aspect of the invention, the devices may be installed in the wellbore wall either permanently or temporarily to form a network of devices for providing selected measurement of one or more downhole parameters. The various aspects of the present invention are described below in reference to Figures 1-6 utilizing
5 exemplary wellbores.

In a preferred embodiment, the flowable device may include a sensor for providing measurements relating to one or more parameters of interest, a memory for storing data and/or instructions, an antenna for transmitting and/or receiving
10 signals from other devices and/or flowable devices in the wellbore and a control circuit or controller for processing, at least in part, sensor measurements and for controlling the transmission of data from the device, and for processing data received from the device. The device may include a battery for supplying power to its various components. The device may also include a power generation device
15 due to the turbulence in the wellbore fluid flow. The generated power may be utilized to charge the battery in the device.

Figure 1 is an illustration of the use of flowable devices during drilling of a wellbore, which shows a wellbore 10 being drilled by a drill string 20 from a surface
20 location 11. A casing 12 is placed at an upper section of the wellbore 10 to prevent collapsing of the wellbore 10 near the surface 11. The drilling string 20 includes a tubing 22, which may be a drill pipe made from joining smaller sections of rigid pipe

or a coiled tubing, and a drilling assembly 30 (also referred to as a bottom hole assembly or "BHA") attached to the bottom end 24 of the tubing 22.

5 The drilling assembly 30 carries a drill bit 26, which is rotated to disintegrate the rock formation. Any suitable drilling assembly may be utilized for the purpose of this invention. Commonly used drilling assemblies include a variety of devices and sensors. The drilling assembly 30 is shown to include a mud motor section 32 that includes a power section 33 and a bearing assembly section 34. To drill the wellbore 10, drilling fluid 60 from a source 62 is supplied under pressure to the
10 tubing 22. The drilling fluid 60 causes the mud motor 32 to rotate, which rotates the drill bit 26. The bearing assembly section 34 includes bearings to provide lateral and axial stability to a drill shaft (not shown) that couples the power section 33 of the mud motor 32 to the drill bit 26. The drilling assembly 30 contains a plurality of direction and position sensor 42 for determining the position (x, y and z coordinates)
15 with respect to a known point and inclination of the drilling assembly 30 during drilling of the wellbore 10. The sensors 42 may include, accelerometers, inclinometers, magnetometers, and navigational devices. The drilling assembly further includes a variety of sensors denoted herein by numeral 43 for providing information about the borehole parameters, drilling parameters and drilling
20 assembly condition parameters, such as pressure, temperature, fluid flow rate, differential pressure across the mud motor, equivalent circulatory density of the

drilling fluid, drill bit and/or mud motor rotational speed, vibration, weight on bit, etc. Formation evaluation sensors 40 (also referred to as the "FE" sensors) are included in the drilling assembly 30 to determine properties of the formations 77 surrounding the wellbore 10. The FE sensors typically include resistivity, acoustic, nuclear and
5 nuclear magnetic resonance sensors which alone provided measurements that are used alone or in combination of measurements from other sensors to calculate, among other things, formation resistivity, water saturation, dielectric constant, porosity, permeability, pressure, density, and other properties or characteristics of the formation 77. A two-way telemetry unit 44 communicates data/signals between
10 the drilling assembly 30 and a surface control unit or processor 70, which usually includes a computer and associated equipment.

During drilling, according to one aspect of the present invention, flowable devices 63 are introduced at one or more suitable locations into the flow of the
15 drilling fluid 60. The flowable devices 63 travel with the fluid 60 down to the BHA 30 (forward flow), wherein they are channeled into a passage 69. A data exchange device 72, usually a read/write device disposed adjacent to or in the passage 69, which can read information stored in the devices 63 (at the surface or obtained during flow) and can write on the devices 63 any information that needs to be sent
20 back to the surface 11. An inductive coupling unit or another suitable device may be used as a read/write device 72. Each flowable device 63 may be programmed

at the surface with a unique address and specific or predetermined information. Such information may include instructions for the controller 73 or other electronic circuits to perform a selected function, such as activate ribs 74 of a force application unit to change drilling direction or the information may include signals for the controller 73 to transmit values of certain downhole measured parameters or take another action. The controller 73 may include a microprocessor-based circuit that causes the read/write unit 72 to exchange appropriate information with the flowable devices 63. The controller 73 process downhole the information received from the flowable devices 63 and also provides information to the devices 63 that is to be carried to the surface. The read/write device 72 may write data that has been gathered downhole on the flowable devices 63 leaving the passage 69. The devices 63 may also be measurement or sensing devices, in that, they may provide measurements of certain parameters of interest such as pressure, temperature, flow rate, viscosity, composition of the fluid, presence of a particular chemical, water saturation, composition, corrosion, vibration, etc. The devices 63 return to the surface 11 with the fluid circulating through the annulus 13 between the wellbore 10 and drill string 22.

The flowable devices returning to the surface designated herein for convenience by numeral 63a are received at the surface by a recovery unit 64. The returning devices 63a may be recovered by filtering magnetic force or other

techniques. The information contained in the returning devices 63a is retrieved, interpreted and used as appropriate. Thus, in the drilling mode, the flowable devices 63 flow downhole where they perform an intended function, which may be taking measurements of a parameter of interest or providing information to a downhole controller 73 or retrieving information from a downhole device. The devices 63a return to the surface (the return destination) via the annulus 13.

During drilling, some of the devices may be lost in the flow process or get attached or stuck to the wall of the wellbore 10. Redundant devices may be supplied to account for such loss. Once the controller 73 has communicated with a device having a particular address, it may be programmed to ignore the redundant device. Alternatively, the controller 73 may cause a signal to be sent to the surface confirming receipt of each address. If a particular address is not received by the downhole device 72, a duplicate device may be sent. The devices 63a that get attached to the wellbore wall 10a (see Figure 2), may act as sensors or communication locations in the wellbore 10. A stuck device may communicate with another flowable device stuck along the wall 10a or with devices passing adjacent the stuck device, thereby forming a communications network. The returning devices 63a can retrieve information from the devices stuck in the well 10. Thus, the flowable devices in one aspect, may form a virtual network of devices which can pass data/information to the surface. Alternatively, some of the devices 63 may be

adapted or designed to lodge against or deposited on the wellbore wall 10a, thereby providing permanent sensors and/or communication devices in the wellbore 10. In one embodiment, the flowable devices may be designed to be deposited on the borehole wall during the drilling process. As one flowable device can communicate with another neighboring flowable device, a plurality of flowable devices deposited on the wellbore wall may form a communications network. As drilling of new formation continues new flowable devices are constantly deposited on the borehole wall to maintain the network. When drilling of the section is completed, the flowable devices may be retrieved from the borehole wall for use in another application. The devices 63 may include a movable element that can generate power due to turbulence in the wellbore fluid, which power can be used to change a resident battery in the flowable devices. Further, the devices 63 may include a propulsion mechanism (as more fully explained in reference to Figure 6) that aids these devices in flowing with or in the fluid 60. The devices 63 usually are autonomous devices and may include a dynamic ballast that can aid such devices to flow in the fluid 60.

Flowable devices may also be periodically planted in the wellbore wall in a controlled operation to form a communication line along the wellbore, as opposed to randomly depositing flowable devices using the hydraulic pressure of the drilling fluid. An apparatus may be constructed as part of the downhole assembly to mechanically apply a force to press or screw the flowable device into the wellbore

5 wall. In this operation, the force required to implant the device may be measured, either by sensors within the flowable device itself or sensors within the implanting apparatus. This measured parameter may be communicated to the surface and used to investigate and monitor rock mechanical properties. The flowable devices
10 may be pumped downhole to the planting apparatus, or kept in a magazine downhole to be used by the planting apparatus. In this case the flowable devices may be permanently installed. Figure 2 which is a schematic illustration of a wellbore, wherein devices made in accordance with the present invention are implanted in the borehole wall during drilling of the wellbore 10 to form a
15 communication network. Figure 2 shows a well 10 being drilled by drill bit 26 at the bottom of a drilling assembly 80 carried by a drilling tubing 81. Drilling fluid 83 supplied under pressure through the tubing 81 discharges at the bottom of the drill bit 26. Flowable devices 63 are introduced or pumped into the fluid 83 and captured or retrieved by a device 84 in the drilling assembly 80. The drilling assembly 80
20 includes an implanting device 85 that implants the retrieved flowable devices 63 via a head 86 into the borehole wall 10a. The devices which are implanted during the drilling of the wellbore 10 are denoted by numeral 63b. The devices 63 may be pumped downhole through a dedicated tubing 71 placed in the drilling tubing 81. If coiled tubing is used as the tubing 81, the tubing 71 for carrying the flowable devices 63 to the implanter 85 may be built inside or outside the coiled tubing.

Alternatively, the devices to be implanted may be stored in a chamber or magazine 83, which deliver them to the implanter 85. The implanted flowable devices 63b in the well 10 can exchange data with each other and/or other flowable devices returning to the surface via the annulus 13 and/or with other devices in the drill string as described above in reference to Figure 1. A communication device 88 may be disposed in the well at any suitable location, such as below the upper casing 12 to communicate with the implanted devices 63b. The communication device 88 may communicate with one or more nearby flowable devices 63b such as a device denoted by numeral 63b, which device then communicates with next device and so forth down the line to the remaining implanted devices 63b. Similarly, the implanted devices 63b communicate uphole up to the devices 63b which communicates with the device 88, thus establishing a two-way communication link or line along the wellbore 10. The device 88 can read data from and write data on the devices 63b. It is operatively coupled to a receiver/transmitter unit 87 and a processor 89 at the surface by a conductor or link 91. The link 91 may be an electrical conduct or a fiber optic link. The processor 89 processes the data received by the receiver/transmitter unit 87 from the devices 63b and also sends data to the devices 63b via the receiver/transmitter 87. The implanted devices 63b may be used to take measurements for one or more selected downhole parameters during and after the drilling of the wellbore 10.

Figure 3 illustrates an alternative method of transporting the devices **63** to a downhole location. **Figure 3** shows a wellbore **101** formed to a depth **102**. For simplicity and ease of understanding, normal equipment and sensors placed in a wellbore are not shown. A fluid conduit **110** is disposed in the wellbore. The conduit **110** runs from a fluid supply unit **112**, forms a U-return **111** and returns to the surface **11**. Flowable devices **63** are pumped into the conduit **110** by the supply unit **112** with a suitable fluid. A downhole device **72a** retrieves information from the flowable devices **63** passing through a channel **70a** and/or writes information on such devices. A controller **73a** receives the information from the flowable devices **63** and utilizes it for the intended purpose. Controller **73a** also controls the operation of the device **72a** and thus can cause it to transfer the required information onto the flowable devices **63**. The flowable devices **63** then return to the surface via the return segment **110a** of the tubing **110**. A retrieval unit **120** at the surface recovers the returning flowable devices **63a**, which may be analyzed by a controller **122** or by another method. The devices **63** may perform sensory and other functions described above in references to **Figure 1**.

Figure 4 is a schematic illustration of a production well **200** wherein flowable devices **209** are released into the produced fluid or formation fluid **204**, which carries these devices to the surface. **Figure 4** shows a well **201** that has an upper casing **203** and a well casing **202** installed therein. Formation fluid **204** flows into

the well 201 through perforations 207. The fluid 204 enters the wellbore and flows to the surface via a production tubing 210. For simplicity and ease of understanding, Figure 4 does not show the various production devices, such as flow control screens, valves and submersible pumps, etc. A plurality of flowable devices 209 are stored or disposed in a suitable container at a selected location 211 in the wellbore 201. The devices 209 are selectively released into the flow of the produced fluid 204, which fluid carries these devices, the released devices are designated by numeral 209a to the surface. The devices 209a are retrieved by a retrieval unit 220 and analyzed. As noted above in reference to Figures 1 and 3, the flowable devices 209a may be sensor devices or information containing devices or both. Periodic release of sensory devices can provide information about the downhole conditions. Thus, in this aspect of the invention, the flowable devices are released in the well 201 to transfer downhole information during the production phase of the well 201.

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Communication in open-hole sections may be achieved using flowable devices in the drilling mud deposited on the borehole wall, or by using implanted flowable devices as described above. In cased hole sections often found above open-hole sections, communications may be achieved in several ways; through flowable devices deposited in the mud filter cake or implanted in the borehole wall during the drilling process, or through flowable devices mixed in the cement which

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fills the annulus between the borehole wall/mud filter cake and the casing, or through a communication channel installed as part of the casing. The latter may include a receiver at the bottom of the casing to pick up information from the devices, and a transmitter to send this information to the surface and vice versa.

5 The communication device associated with the casing could be an electrical or fibre-optic or other type of cable, an acoustic signal or an electromagnetic signal carried within the casing or within the earth, or other methods of communication. In conclusion, a communication system based on the use of flowable devices may be used in combination with other communication methods to cover different sections
10 of the wellbore, or to communicate over distances not covered by a wellbore.

Another example of using flowable devices in combination with other communication systems is a multilateral well. One or more laterals of the well may have a two-way communication system with flowable devices, while one or more
15 laterals of the same well may not have a full two-way communication system with the flowable devices. In one embodiment of the invention, the first lateral is equipped with a single tube or a U-tube that allows flowable devices containing information from surface to travel to the bottom of the first lateral. The second lateral is not equipped with a tubing, but has flowable devices stored in a downhole
20 magazine. A message to the second lateral is pumped into the first lateral. From the receiver station in the first lateral, information such as a command to release a flowable device in the second lateral, is transmitted from the first lateral to the

second lateral through acoustic or electromagnetic signals through the earth. Upon receipt of this information in the second lateral, the required task, such as writing to and releasing a flowable device or initiating some action downhole is performed. Provided the distance and formation characteristics allow transmission of signal
5 through the earth formation, the same concept can be used to communicate between individual wellbores.

Figure 5 is an exemplary schematic illustration of an multilateral production well 300, wherein flowable devices are pumped into one branch or lateral and then
10 utilized for communication between the laterals. Figure 5 shows a main well section 301 having two branch wells or laterals 301a and 301b. In the exemplary lateral wellbore configuration of Figure 5, both wells 301a and 301b are shown to be production wells. Well 301a and 301b produce fluids (hydrocarbons) which are shown by arrow 302a and 302b, respectively. Flowable devices 63 are pumped into
15 the first lateral 301a via a tubing 310 from a supply unit 321 at the surface 11. The devices 63 are discharged at a known depth 303a where a receiver unit 370a retrieves data from the devices 63. The devices return to the surface with the produced fluid 302a. The returning devices from wellbore 301 are denoted by 63d. A transmitter unit 380 transmits signals 371 in response to information retrieved
20 from the flowable devices 63. A second receiver 370b in the second lateral 301b receives signals 371. A controller unit or processor 382 utilizes the received signals

to perform an intended function or operation, which may include operating a device downhole, such as a valve, a sliding sleeve, or a pump, etc. Flowable devices 63c may be disposed in magazine 383 in the second lateral 301b and released into the fluid flow 302b by the controller 382. The devices 63d and 63c flowing uphole are
5 retrieved at the surface by a receiver unit 320 and the data carried by the flowable devices 63c and 63d is processed by the processor 322. It should be noted that Figure 5 is only one example of utilizing the flowable devices in multiple wellbores. The wells selected for intercommunication may be separate wells in a field. The signals 371 may be received by instruments in one or more wells and/or at the
10 surface for use in performing an intended task.

Figure 6 shows a block functional diagram of a flowable device 450 according to one embodiment of the present invention. The device 450 is preferably encapsulated in a material 452 that is suitable for downhole environment such as
15 ceramic, and includes one or more sensor elements 454, a control circuit or controller 456 and a memory unit 458. A resident power supply 460 supplies power to the sensor 454, controller 456, memory 458 and any other electrical component of the device 450. The controller 456 may include a processor that interacts with one or more programs in the device to process the data gathered by the device
20 and/or the measurements made by the device to compute, at least partly, one or more parameters of interest, including results or answers. For example, the device

450 may calculate a parameter, change its future function and/or transmit a signal in response to the calculated parameter to cause an action by another flowable device or a device in the wellbore. For example, the device may determine a detrimental condition downhole, such as presence of water and then send a signal

5 to a fluid flow control device in the wellbore to shut down a production zone or the well. The device may be designed to have sufficient intelligence and processing capability so it can take any number of different actions in the wellbore. A power generation unit that generates electrical power due to the turbulence in the flow may be incorporated in the device 450 to charge a battery (resident power supply) 460.

10 An antenna 462 is provided to transmit and/or receive signals, thereby providing one-way or two-way communication (as desired) between the flowable device 450 and another device, which may be a flowable device or a device located downhole or at the surface. The device 450 may be programmed at the surface or downhole to carry data and instructions. The surface information programmed into a flowable

15 device is read by a device in the wellbore while the downhole programmed information may be read at the surface or by reading devices downhole. The device 450 may transmit and receive signals in the wellbore and thus communicate with other devices. Such a flowable device can transfer or exchange information with other devices, establish communication link along the wellbore, provide two-way

20 communication between surface and downhole devices, or between different wellbores in a field or laterals of a wellbore system, and establish a communication network in the wellbore and/or between the surface instrumentation and downhole

devices. Each such device may be coded with an identification number or address, which can be utilized to confirm the receipt or transfer of information by the devices deployed to receive the information from the flowable device 450. In one method, the flowable device 450 may be sequentially numbered and introduced into the fluid flow to be received at a target location. If the receiving device receives a flowable device, it can cause a signal to be sent to the sending location, thereby confirming the arrival of a particular device. If the receiving device does not confirm the arrival of a particular device, a second device carrying the same information and the address may be sent. This system will provide a closed loop system for transferring information between locations.

In another aspect of the invention, the flowable device may contain a chemical that alters a state in response to a downhole parameter, which provides a measure of a downhole parameter. Other devices, such as devices that contain biological mass or mechanical devices that are designed to carry information or sense a parameters may also be utilized. In yet another aspect, the flowable device may be a device carrying power, which may be received by the receiving device. Thus, specially designed flowable devices may be utilized to transfer power from one location to another, such as from the surface to a downhole device.

The flowable device 450 may include a ballast 470 that can be released or activated to alter the buoyancy of the device 450. Any other method also may be

utilized to make the device with variable buoyancy. Additionally, the device **450** may also include a propulsion mechanism **480** that can be selectively activated to aid the device **450** to flow within the fluid path. The propulsion mechanism may be self-activated or activated by an event such as the location of the device **450** in the fluid or its speed.

While the foregoing disclosure is directed to the preferred embodiments of the invention, various modifications will be apparent to those skilled in the art. It is intended that all variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.

WHAT IS CLAIMED IS:

- 1 1. A method of utilizing discrete devices in a wellbore wherein a working fluid
2 provides fluid flow path for moving said discrete devices from a first location of
3 introduction of said devices into the flow path to a second location of interest, said
4 method comprising:
- 5 - selecting at least one flowable discrete device constituting a data
6 carrier that is adapted to be moved in the wellbore at least in part by
7 the working fluid ("flowable device");
 - 8 - introducing the at least one flowable discrete device into the fluid flow
9 path at the first location to cause the working fluid to move the at least
10 one flowable device to the second location of interest; and
 - 11 - providing a data exchange device in the fluid flow path for effecting
12 data exchange with the at least one flowable discrete device.
- 1 2. The method of claim 1, wherein selecting the at least one flowable device
2 comprises selecting the at least one flowable device from a group consisting of: (i)
3 a device having a sensor for providing a measure of a parameter of interest; (ii) a
4 device having a memory for storing data therein; (iii) a device carrying energy that
5 is transmittable to another device; (iv) a solid mass carrying a chemical that alters
6 a state when said solid mass encounters a particular property in the wellbore; (v) a

7 device carrying a biological mass; (vi) a data recording device; (vii) a device that is
8 adapted to take a mechanical action, and (viii) a self-charging device due to
9 interaction with the working fluid in the wellbore.

1 3. The method of claim 1, wherein said selecting the at least one flowable
2 device comprises selecting a device that provides a measure of a parameter of
3 interest selected from a group consisting of: (i) pressure; (ii) temperature; (iii) flow
4 rate; (iv) vibration; (v) presence of a particular chemical in the wellbore; (vi)
5 viscosity; (vii) water saturation; (viii) composition of a material; (ix) corrosion; (x)
6 velocity; (xi) a physical dimension; and (xi) deposition of a particular matter in a fluid.

1 4. The method of claim 1, wherein selecting at least one flowable device
2 comprises selecting a device that comprises:
3 - a sensor for providing a measurement representative of a parameter
4 of interest;
5 - a memory for storing data relating at least in part to the parameter of
6 interest;
7 - a source of power for supplying power to a component of said
8 flowable device; and
9 - a controller for determining data to be carried by said memory.

1 5. The method according to claim 4 further comprising providing a transmitter
2 for the at least one flowable device for effecting data exchange with the flowable
3 device.

1 6. The method of claim 5, wherein effecting the data exchange comprises
2 communicating with said at least one flowable device by a method selected from a
3 group consisting of: (i) electromagnetic radiation; (ii) optical signals; and (iii) acoustic
4 signals.

1 7. The method of claim 1, wherein selecting the at least one flowable device
2 comprises selecting a flowable device that is adapted to carry data that is one of (i)
3 prerecorded on the at least one flowable device; (ii) recorded on the at least one
4 flowable device downhole; (iii) self recorded by the at least one flowable device; (iv)
5 inferred by a change of a state associated with the at least one flowable device.

1 8. The method of claim 1, wherein selecting the at least one flowable comprises
2 selecting a device from a group of devices consisting of: (i) a device that is freely
3 movable by the working fluid; (ii) a device that has variable buoyancy; (iii) a device
4 that includes a propulsion mechanism that aids the at least one flowable device to

5 flow within the working fluid; (iv) a device that is movable within by a superimposed
6 field; and (v) a device whose movement in the working fluid is aided by the
7 gravitational field.

1 9. The method of claim 1, wherein selecting the at least one flowable device
2 comprises selecting a device that is one of: (i) resistant to wellbore temperatures;
3 (ii) resistant to chemicals; (iii) resistant to pressures in wellbores; (iv) vibration
4 resistant; (v) impact resistant; (vi) resistant to electromagnetic radiation; (vii)
5 resistant to electrical noise; and (viii) resistant to nuclear fields.

1 10. The method of claim 1, wherein said introducing the at least one flowable
2 device into the working fluid further comprises delivering the at least one flowable
3 device to the working fluid by one of (i) an isolated flow path; (ii) a chemical injection
4 line; (iii) a tubing in a wellbore; (iv) a hydraulic line reaching the second location of
5 interest and returning to the surface; (v) through a drill string carrying drilling fluid;
6 (vi) through an annulus between a drill string and the wellbore; (vii) through a tubing
7 disposed outside a drill string; and (viii) in a container that is adapted to release said
8 at least one flowable device in the wellbore.

1 11. The method of claim 1 further comprising recovering said at least one
2 flowable device.

1 12. The method of claim 14, wherein recovering the at least one flowable device
2 comprises recovering the at least one flowable device by one of (i) fluid to solid
3 separation; and (ii) fluid to fluid separation.

1 13. The method of claim 1, wherein said introducing the at least one flowable
2 device includes introducing a plurality of flowable devices each such flowable device
3 adapted to perform at least one task.

1 14. The method of claim 13, wherein said introducing a plurality of flowable
2 devices comprises one of (i) timed release; (ii) time independent release; (iii) on
3 demand release; and (iv) event initiated release.

1 15. The method of claim 1, wherein introducing said at least one flowable device
2 comprises delivering a plurality of flowable devices into fluid circulating in a wellbore
3 to cause at least a number of the flowable devices to remain in the wellbore at any
4 given time, thereby forming a network of the flowable devices in the wellbore.

1 16. The method of claim 15, wherein the flowable devices in said plurality of
2 devices are adapted to communicate information with other devices, thereby
3 forming communication network in the wellbore.

1 17. The method of claim 1 further comprising providing a unique address to the
2 at least one flowable device.

1 18. The method of claim 1 further comprising providing a data communication
2 device in the wellbore for communicating with the at least one flowable device.

1 19. The method of claim 18 further comprising causing the data communication
2 to exchange data with the at least one flowable device and to transmit a signal
3 confirming said data exchange.

1 20. The method of claim 1, wherein said selecting said at least one flowable
2 device comprises selecting the at least one flowable device that includes a sensor
3 that is one of (i) mechanical (ii) electrical; (iii) chemical; (iv) nuclear; and (v)
4 biological.

1 21. The method of claim 1 further comprising implanting a plurality of spaced
2 apart flowable devices in said wellbore during drilling of said wellbore.

1 22. The method of claim 7 further comprising receiving the data carried by said
2 at least one flowable device by a downhole device and transmitting a signal in
3 response to said received signal to a device located outside said wellbore.

1 23. The method according to claim 22 further comprising said device outside said
2 wellbore at a location that is one of: (i) in a lateral wellbore associated with said
3 wellbore; (ii) a separate wellbore; (iii) at the surface; and (iv) in an injection well.

1 24. A wellbore system utilizing at least one flowable device constituting a data
2 carrier that is adapted to be moved by a fluid flowing in the wellbore comprising:

3 (a) a forward fluid flow path associated with the wellbore for moving the
4 at least one flowable device from a first location of introduction of the
5 at least one flowable device into the forward fluid path to a second
6 location of interest;

7 (b) a data exchange device at the second location of interest for effecting
8 data exchange with the at least one flowable device that is one of (i)
9 retrieving information carried by the at least one flowable device; or
10 (ii) inducing selected information on the at least one flowable device.

1 25. The wellbore system of claim 24 further comprising a return fluid flow path
2 for moving the at least one flowable device from the second location of interest to
3 a return destination.

1 26. The wellbore system of claim 24, wherein the first location of introduction and
2 the return destination are at the surface.

1 27. The wellbore system of claim 25, wherein the forward flow path is through a
2 drill string utilized for drilling the wellbore and the return fluid flow path is an annulus
3 between the drill string and the wellbore.

1 28. The wellbore system of claim 25, wherein (i) the forward fluid flow path
2 comprises a first section of a u-tube extending from the first location to the second
3 location of interest and (ii) the return path comprises a second section of the u-tube
4 returning to the return destination.

1 29. The wellbore system of claim 24, wherein the second location of interest is
2 in the wellbore and the data exchange device is located proximate said second
3 location of interest.

1 30. The wellbore system of claim 24 further comprising a controller for
2 performing an operation that is one of (i) retrieving information from the at least one
3 flowable device from the data exchange device, or (ii) causing the data exchange
4 devices to induce a particular information onto the at least one flowable device.

1 31. The wellbore system of claim 25 further comprising a control unit for
2 processing data contained in the flowable device returning to the destination.

1 32. The wellbore system of claim 30, wherein the controller performs at least one
2 operation in response to the data retrieval from the at least one flowable device.

1 33. A system for implanting at least one flowable device in the wall of the
2 wellbore during drilling of the wellbore, comprising:

- 3 - a drill string having a drill bit at end thereof for drilling the wellbore;
- 4 - a source of drilling fluid for supplying the drilling fluid to the drill string;
- 5 - a source for introducing at least one flowable device into the drilling
6 fluid; and
- 7 - an implanting device carried by the drill string uphole of the drill bit,
8 said implanting device receiving the at least one flowable device from
9 the drilling fluid and implanting the at least one flowable device in the
10 wall of the wellbore.

1 34. A method of utilizing flowable devices in a wellbore carrying a fluid from a
2 downhole location to the surface, each flowable device constituting a data carrier
3 and adapted to be moved by the fluid, said method comprising:

- 4 - locating a plurality of flowable devices at a selected location in a
5 wellbore; and
- 6 - selectively releasing the flowable devices into fluid, thereby moving
7 the flowable devices carry data from the selected location in the
8 wellbore to the surface.

9 35. The method of claim 34, wherein the locating of a plurality of the flowable
10 devices includes locating said devices in a magazine from where said devices are
11 individually releaseable into the flow of the fluid.

1 36. The method of claim 34 further comprising providing a controller in the
2 wellbore for inducing information n to the at flowable devices prior to their release
3 into the fluid.

1 37. The method of claim 34, wherein the releasing the flowable devices includes
2 at least one of (i) releasing the flowable devices at predetermined time intervals, (ii)
3 releasing a flowable device upon the occurrence of a particular event; or (iii)
4 releasing the flowable devices periodically.

1 38. A discrete flowable device adapted to be moved at least partially by a fluid
2 flowing in a wellbore, comprising:

- 3 - a sensor for taking measurements relating to a wellbore parameter;
- 4 - a controller for processing the sensor measurements;
- 5 - a memory for storing data;
- 6 - a power source for supplying power to elements of the flowable
- 7 device;
- 8 - an antenna for communicating information to a device external to the
- 9 flowable device; and

10 a body housing the sensor, controller, memory and the power source,
11 which body is adapted to protect the device from wellbore conditions.

1 39. The discrete flowable device according to claim 38 further comprising an
2 external member that interacts with fluid in the wellbore to aid in generating
3 electrical energy.

1 40. The discrete flowable device according to claim 39, wherein the electrical
2 energy is utilized to charge the power supply.

1 41. The discrete flowable device according to claim 38 further comprising a
2 buoyancy device to alter the buoyancy of the discrete flowable device.

1 42. The discrete flowable device according to claim 38 further comprising a
2 propeller for aiding the discrete flowable device to flow in the wellbore.

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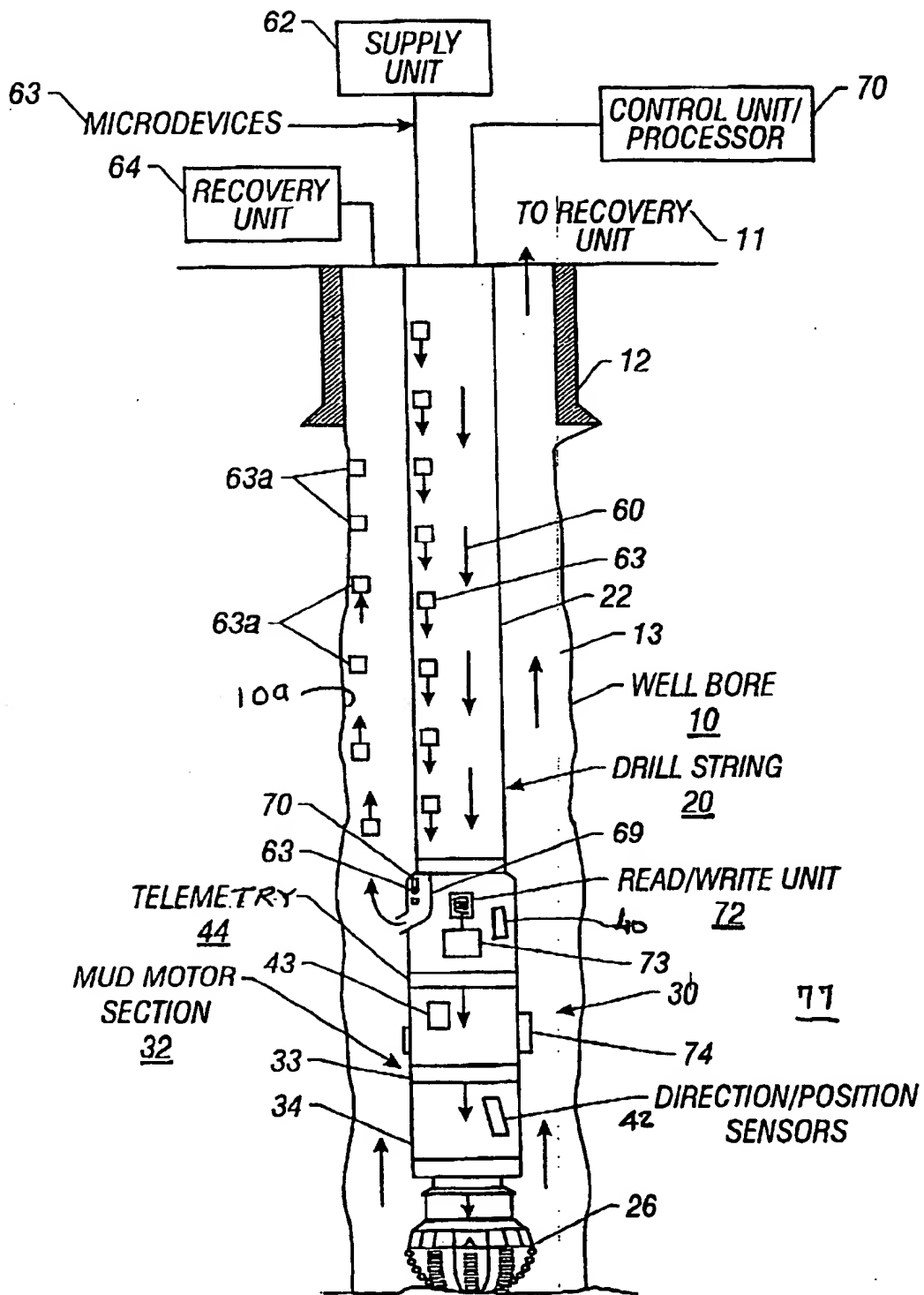


FIG. 1

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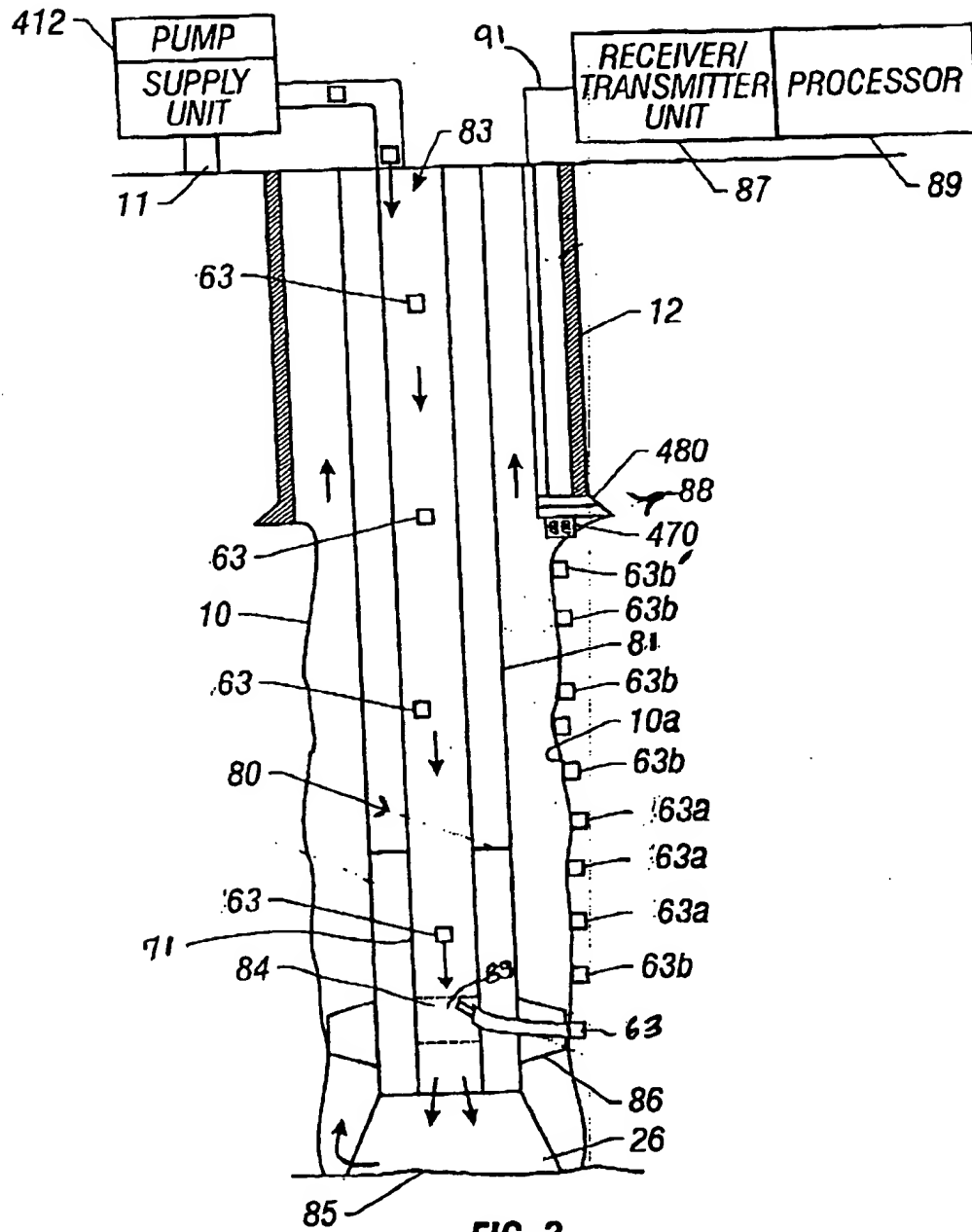


FIG. 2

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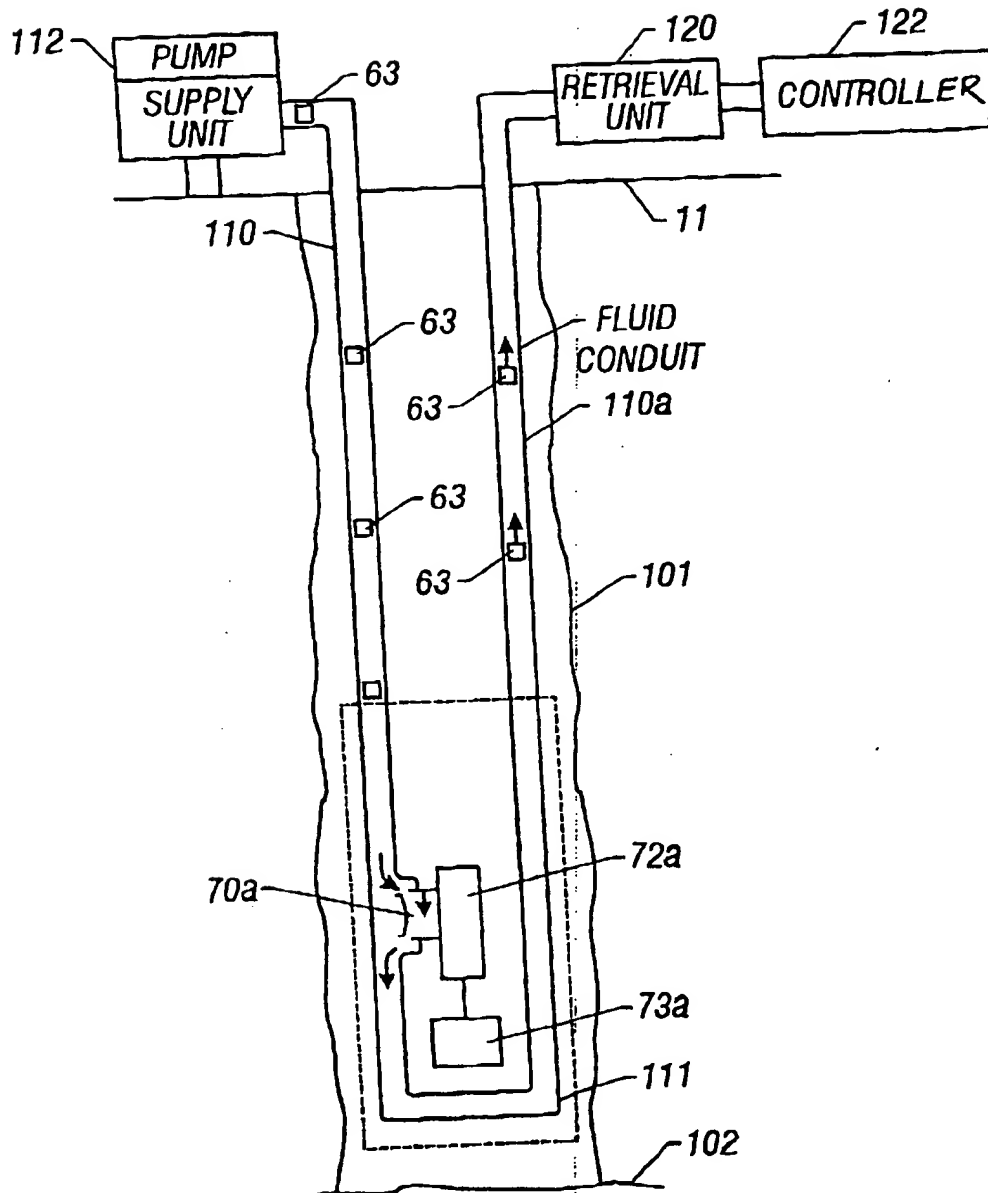


FIG. 3

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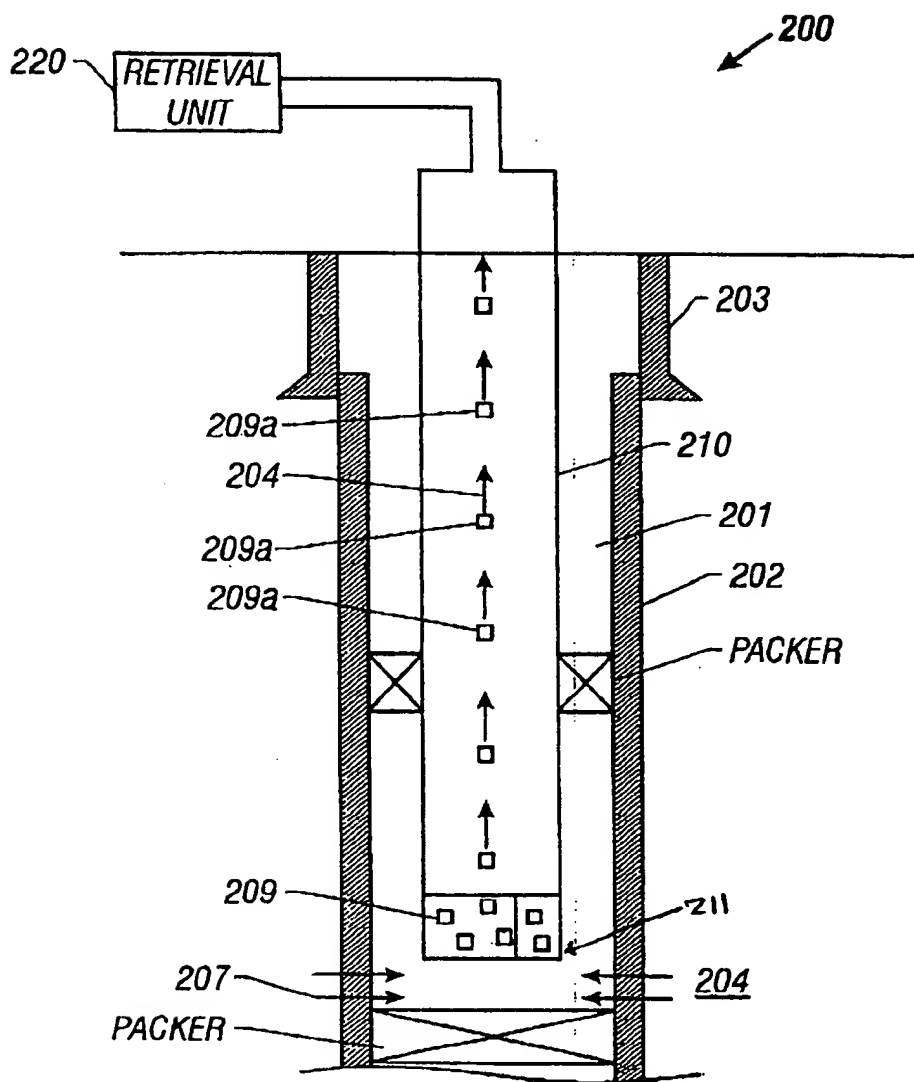


FIG. 4

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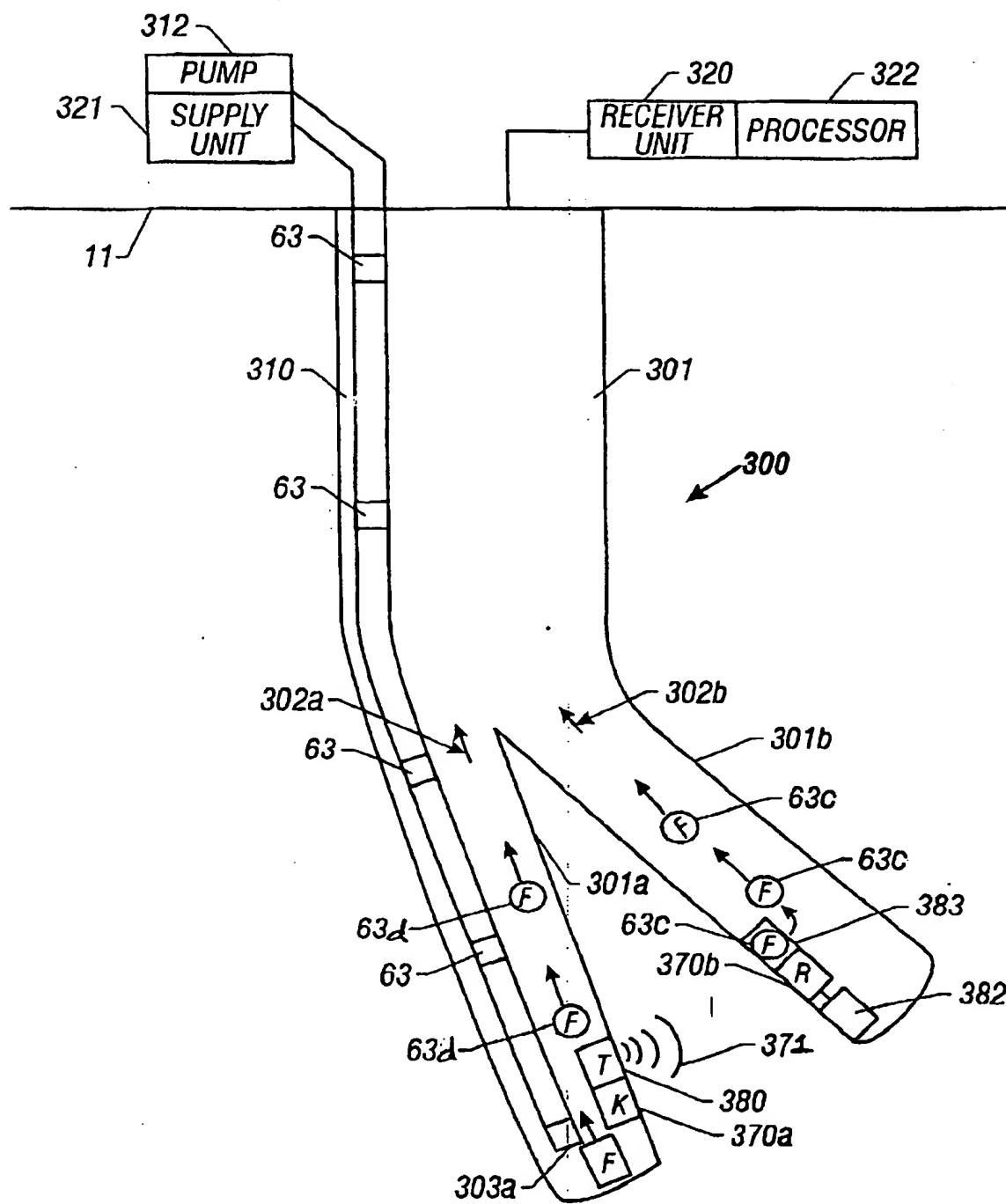


FIG. 5

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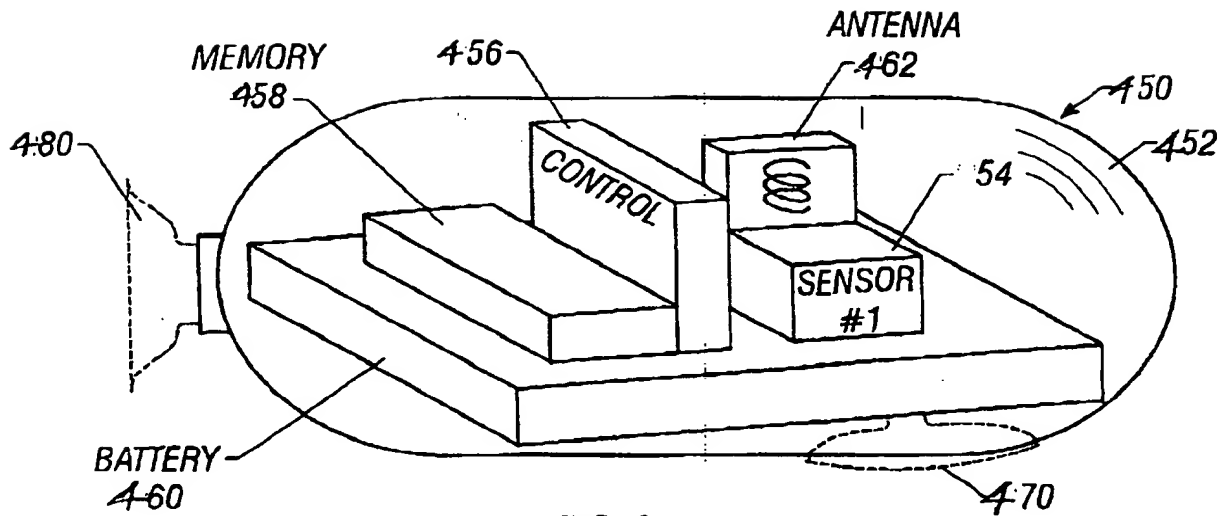


FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 00/14464

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 E21B47/01 E21B47/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, TULSA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	WO 99 66172 A (SHELL CANADA LTD ;SHELL INT RESEARCH (NL)) 23 December 1999 (1999-12-23) page 14, line 7 -page 15, line 21 ---	1-42
A	WO 98 57030 A (BAKER HUGHES INC) 17 December 1998 (1998-12-17) page 10, line 11 - line 22 page 13, line 20 - line 25 ---	1-42
A	EP 0 882 871 A (SCHLUMBERGER SERVICES PETROL ;ANADRILL INT SA (PA)) 9 December 1998 (1998-12-09) column 5, line 15 - line 19 -----	33

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

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Garrido Garcia, M

INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

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